ENHANCEMENT OF PRODUCTION OF BIOGAS FROM PALM OIL MILL EFFLUENT (POME)

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering

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ABSTRACT

Energy demand is increasing continuously due to rapid growth in population and industrialization development. The major energy demand is provided from the conventional energy sources such as coal, oil, natural gas, etc. In every country is facing with these conventional fuels, are depletion of fossil fuels and deterioration of environment. Meanwhile, the Malaysian oil palm industry is an important industry but the waste organic from palm oil mill effluent (POME) is a contributed to global warming phenomena. The experiment for capture gas methane will be one of the alternative ways to encounter this problem. It investigated to increase the gas CH_4 and decrease the gas CO_2 to a biogas production. The parameters that have been focused throughout identified condition temperature and monitoring optimum day in bioreactor. Gas Chromatography is used to detect the concentration time in weekly for one month. Temperature in the pilot plant is not to control but the result is take for analysis. Meanwhile the pattern of the concentration CH_4 by a weekly was taken. The study shows, the mesophilic condition is highest concentration methane than thermophilic condition. POME in the bioreactor $500m^3$ after a fortnight needed to discharge and uploads a quarter of volume in bioreactor to get optimum condition. As a conclusion, the applicability of temperature and time in bioreactor was enhancement the biogas production and can be used to generate electricity. Biogas capture also has resulted in substantial greenhouse gasses (GHG) reduction.

ABSTRAK

Permintaan tenaga semakin meningkat secara berterusan disebabkan pertumbuhan pesat dalam jumlah penduduk dan pembangunan perindustrian. Permintaan tenaga daripada sumber-sumber tenaga konvensional seperti arang batu, minyak, gas asli,dan sebagainya memainkan peranan utama. Setiap negara sedang menghadapi permasalahan berkenaan bahan api konvensionalini, kekurangan bahan api fosil dan kemerosotan alam sekitar. Sementara itu, industri kelapa sawit Malaysia merupakan industry utama di Malaysia tetapi sisa organik daripada kilang minyak sawit effluen (POME) menyumbang kepada fenomena pemanasan global. Pengumpulan gas metana merupakan salah satu cara alternative untuk menangani masalah ini. Dengan meningkatkan CH_4 gas dan mengurangkan gas CO_2 dalam proses penghasilan biogas. Parameter yang telah boleh dikenal pasti terdiri daripada suhu dan jumlah hari yang diperlukan semasa berlakunya process di dalam bioreaktor. Kromatografi gas digunakan untuk mengesan jumlah peratusan gas metana. Suhu dalam loji perintis bukan untuk dikawal tetapi suhu akan diambil untuk di analisis. Sementara itu, corak gas metana dalam semniggu selama sebulan akan di rekod. Kajian menunjukkan, keadaan mesophilic memperolehi peratusan gas metana yang tinggi daripada keadaan thermophilic. Loji perintis yang berisipadu 500m^3 pemperlihatkan penurunan peratusan selepas dua minggu. Satu pertiga daripada isipadu lodi perintis akan dilepaskan dan satu pertiga POME yang baharu akan menggantikannya. Secara kesimpulan, penggunaan suhu dan tempoh masa dalam loji perintis memperlihatkan corak peratusan pengeluaran biogas. Biogas boleh digunakan untuk menjana tenaga elektrik. Pengumpulan biogas juga telah mengurangkan kesan terhadap kesan rumah hijau.

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%	Percentage
BOD	Biological Oxygen Demand
CH_4	Methane
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
FFB	Fresh Fruit Bunch
GHG	Green House Gasses
POME	Palm Oil Mill Effluent
VFA	Volatile Fatty Acid

CHAPTER 1

INTRODUCTION

1.1.1 Introduction

Malaysia is the largest producer of palm oil, the third largest for rubber and fourth for cocoa. There were more than 3.79 million hectares of land, occupying more than one-third of the total cultivates area and 11% of the total land area, under palm oil cultivation in Malaysia in the year 2003 (Yusoff and Hassan 2007).

Effluents from palm oil mills processing plant have been identified as the major cause of the rapid deterioration of the aquatic environmental in the 1960s as well as 1970s. There an in fact the largest source of water pollution during the period (DOE 1991). Palm oil mill effluent (POME) is generated mainly from oil extraction, washing and cleaning process in the mill. These contain cellulosic material, fat, oil and grease (Agamuthu 1995). Discharging unthread effluent into water streams may cause considerable environmental problems (Dais and Reilly 1980) due to its high biochemical oxygen demand, BOD (25,000 mg L^{-1}), chemical oxygen demand, COD (53,630 mg L^{-1}), oil and grease (8,370 mg L^{-1}), total solids (43,635 mg L^{-1}) and suspended solids (19,020 mg L^{-1}) (Ma 1995,2000). The palm oil mill industry in Malaysia has thus been identified as the one discharging the largest pollution load into rivers throughout the country (Hwabg et al. 1978).

In addition to biomass, palm oil mills also generate large quantities of liquid wastes, known as palm oil mill effluent (POME), which due to its high biochemical oxygen demand (BOD), is required by law to be treated to an acceptable level before it can be discharged into a watercourse. About 0.7tonne of POME is generated for every tonne of FFB processed. Hence in 2001, the palm oil industry generated about 42.7 million tonne of POME. All palm oil mills used anaerobic process to treat their effluents. Biogas is a gaseous product of the anaerobic process. About 28.8 m^3 of biogas are generated from every tonne of POME digested.

Thus in 2001, palm oil industry was generated about 1230 million cubic meters of biogas. The biogas comprising about 65% methane and 35% carbon dioxide is a good source of energy with a heat value of 4740 kcal m^{-3}. It was reported that in a gas engine, about 1.8 kWhr of electricity could be generated from 1 m^3 of biogas. Thus in 2001, the biogas produced by the palm oil mills could have generated about 2214 million kWhr of electricity. It was more than sufficient to meet the energy demand by all the palm oil mills. Unfortunately, only a few palm oil mills that need the extra energy for its subsidiary industries harness the biogas for heat and electricity generation. In terms of carbon credit, if all the biogas (instead of diesel) were used to generate electricity, the palm oil industry would have prevented 1040 million kilogrammes of carbon dioxide from being emitted to the atmosphere. This amounts to a carbon credit of US$ 10.4 million. Both methane and carbon dioxide are GHG that contribute to global warning. Methane is known to be more potent than carbon dioxide. Based on their global warming potential, methane is 21 times more potent than carbon dioxide over a 1000-year period (Tong, 2002). The potency of methane can be reduced if it is burnt.

1.1.2 Problem Statement

There are currently about 360 active palm oil mills in Malaysia with a combined annual CPO production capacity of about 15 million tonnes (Malaysian Palm Oil Promotion Council, 2005). On an average, in standard palm oil mills, each tonne of fresh fruit bunch (FFB) processed generates about 0.7 tonne of liquid waste comprising of about 26.3 kg of BOD, 53 kg of COD, 19 kg of suspended solids (SS) and 6 kg of oil and grease. This amounts to a population equivalent of around 60 million in terms of COD (Thani *et al.*, 1999). Also, palm oil mill wastewater treatment systems are one of the major sources of greenhouse gases in Malaysia due to their biogas emission (36 % CH4 with a flow rate of 5.4 l/min.m^2) from open digester tanks and/or anaerobic ponds (Yacob *et al.*, 2005). Therefore, palm oil mills in Malaysia face the challenge of balancing environmental protection, their economic viability, and sustainable development after the Department of Environment enforced the regulation for the discharge of effluent from the crude palm oil (CPO) industry, under the Environmental Quality order and regulations, 1997. Thus, there is an urgent need to find an efficient and practical approach to preserve the environment while maintaining the sustainability of the economy.

1.3 Objective

The purpose of this thesis is:

- To increase percent of CH_4 and decrease CO_2 emission from palm oil mill effluent (POME) for a biogas production.
- To study relevant condition temperatures of maximize biogas production from palm oil mill effluent (POME).
- To obtain the maximum of production CH_4 based on cycle retention time to enhance the production methane from palm oil mill effluent (POME).

1.2 Scope of the research work

In order to achieve the target, extra effort and focus have to be done with the topic of the enhancement of production biogas from palm oil mill effluent (POME).

- Firstly there are should studies the effect of temperature in which value can be obtain to the biogas production. The range temperature that suitable is 40^0C-60^0C because it will affect the bacteria growth meanwhile to produce the production of biogas.
- In the other hand, the method in the process of biogas that could enhancement/effect the biogas production should be known in order to make a work more efficient. For the most important is a analyse gas and criteria will produce from the palm oil mill effluent (POME) using a gas chromatography.
- Last but not least, the effect of cycle retention time in concentration CH_4 in weekly will be analysing. The suitable of the retention time should be identified to enhancement the production of biogas from a palm oil mill effluent (POME).

Rationale & Significance of Study

- Section 51 Environment Quality Act 1974 for environmental control of palm oil mills discharge - standards for the emission and discharge or deposits of pollutants into the environment.
- The emission of the methane which partly contributed to global warming phenomena
- Low costs of raw material and renewable alternative energy contribution

CHAPTER 2

LITERATURE REVIEW

2.1 Palm Oil Processing Industry

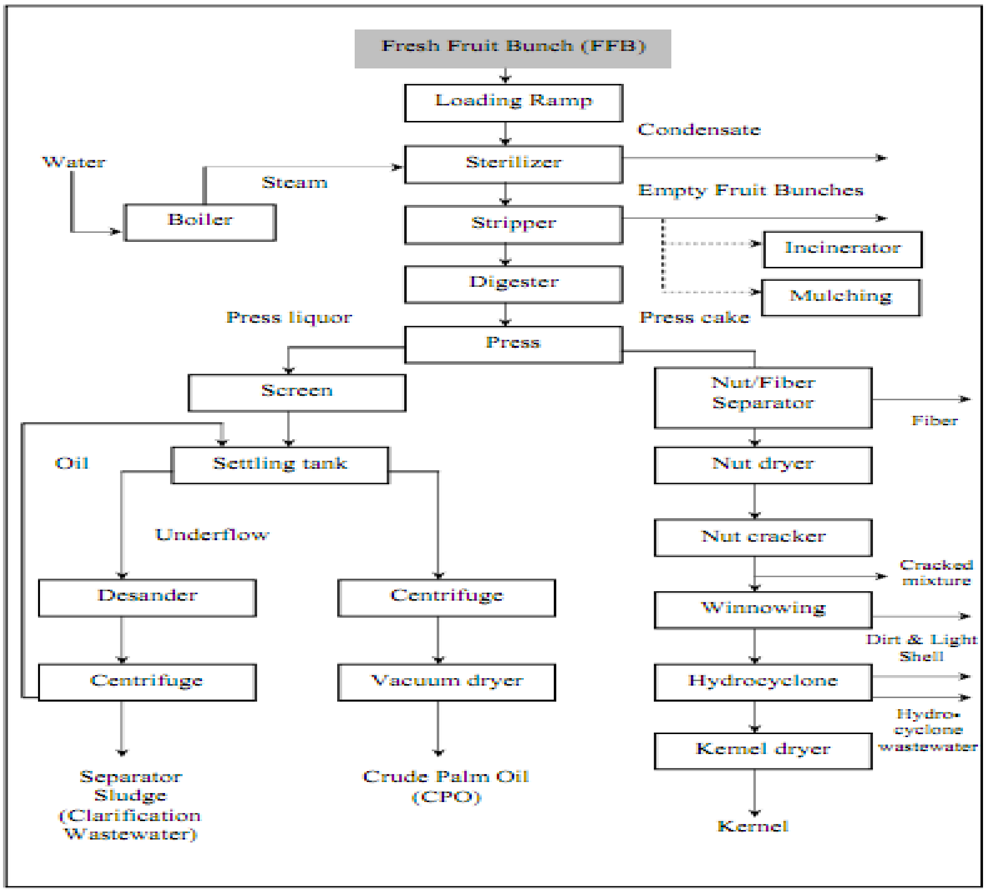

Figure 2.1: Process flow of typical palm oil milling (Industrial Process and The Environment, 1999)

After harvest the palm oil fruit, the fresh fruit bunches (FFB) are transported to the mills for processing. Each FFB consists of hundreds of fruits, each of which containing a nut surrounded by a bright orange pericarp which contains the palm oil. These FFBs are sterilized with steam at a pressure of 3 bars and a temperature of 140°C for 75-90 min. The objectives of this process are to prevent further formation of free fatty acids due to enzyme action, facilitate stripping and prepare the fruit mesocarp for subsequent processing. The steam condensate coming out of the sterilizer constitutes as one of major sources of liquid effluent (Thani et al., 1999).

After sterilization, the FFBs are fed to a rotary drum-stripper where the fruits are stripped from bunches. The detached fruits are passed through the bar screen of the stripper and are collected below by a bucket conveyor and discharged into a digester. In the digester, the fruits are mashed by the rotating arms. In this stage, the mashing of the fruits under heating breaks the oil-bearing cells of the mesocarp. Twin screw presses are generally used to press out the oil from the digested mash of fruit under high pressure. Hot water is added to enhance the flow of the oils. The crude oil slurry is then fed to a clarification system for oil separation and purification. The fibre and nut (press cake) are conveyed to a depericarper for separation (Thani et al., 1999).

The crude palm oil (CPO) from the screw presses consists of a mixture of palm oil (35-45%), water (45-55%) and fibrous materials in varying proportion. It is then pumped to a horizontal or vertical clarification tank for oil separation. In this unit, the clarified oil is continuously skimmed-off from the top of the clarification tank. It is then passed through a high speed centrifuge and a vacuum dryer before sending it to the storage tanks.

The press cake discharged from the screw press consists of moisture, oily fibre and nuts, and the cake is conveyed to a depericarper for nuts and fibres separation. The fibre and nuts are separated by strong air current induced by a suction fan. The fibre is usually sent to boiler house and is used as boiler fuel.

Meanwhile, the nuts are sent to a rotating drum where any remaining fibre is removed before they are sent to a nut cracker. Hydrocyclone is commonly used to separate the kernels and shells. The discharge from this process constitutes the last source of wastewater stream (Chow and Ho, 2000).

2.2 The Origin of Palm Oil Mill Effluent

From the palm oil processing plant, it will produce a waste which is palm oil mill effluent. This oily waste is produced in large volumes and contributes major problem to the palm oil processing mill's waste stream. Thus it has to be treated efficiently because it may have a significant impact on the environment if they are not dealt with properly.

2.2.1 Palm Oil Mill Effluent (POME)

The production of palm oil results in the generation of large quantities of polluted wastewater commonly referred to as palm oil mill effluent (POME). Typically, 1 tonne of crude palm oil production requires 5-7.5 tonnes of water; over 50 % of which ends up as POME (Ma, 1999a). Based on palm oil production in 2005 (14.8 million tonnes), an average of about 53 million m^3 POME is being produced per year in Malaysia (Malaysia Palm Oil Production Council, 2006).

POME comprises a combination of the wastewaters which are principally generated and discharged from the following major processing operations as seen early in figure 2.1.

- Sterilization of FFB - sterilizer condensate is about 36% of total POME;
- Clarification of the extracted CPO - clarification wastewater is about 60% of total POME;

• Clay bath Separation (Hydrocyclone) of separation of cracked mixture of kernel and shell-hydrocyclone wastewater is about 4% of total POME.

There are other minor sources of relatively clean wastewater that may be included in the combined mill effluent POME which is sent to the wastewater stream. These include turbine cooling water and steam condensates, boiler blow-downs, overflows from the vacuum dryers and some floor washings. The volume of the combined POME discharged depends to a large extent on the milling operations.

Distinctive quality characteristics of the individual wastewater streams from the three principal sources of generation are presented in Table 2.1. POME, when fresh is a thick brownish in color colloidal slurry of water, oil and fine cellulosic fruit residues. POME is charged at a temperature of between 80°C and 90°C and it is slightly acidic with a pH between 4 to 5. The characteristics of a usual raw combined POME are presented in Table 2.2. Table 2.2 attests that POME has a very high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which is 100 times more than the domestic sewage. POME is a non-toxic waste, as no chemical is added during the oil extraction process.

Table 2.1 Characteristics of individual wastewater streams (Industrial Processes and The Environment, 1999)

Parameters	**Sterilizer Condense**	**Oil Clarification Wastewater**	**Hyrocyclone Wastewater**
pH	5.0	4.5	-
Oil &Grease	4,000	7,000	300
BOD; 3-day, 30°C	23,000	29,000	5,000
COD	47,000	64,000	15,000
Suspended Solid	5,000	23,000	7,000
Dissolved Solids	34,000	22,000	100
Ammonical Nitrogen	20	40	-
Total Nitrogen	500	1,200	100

*All units are in mg/l except for pH

However it contains appreciable amounts of N, P, K, Mg and Ca which are the vital nutrient elements for plant growth (Industrial Processes & The Environment, 1999).

Table 2.2: Characteristics of combined palm oil mill effluent (POME) (Ma, 2000).

Parameter	**Average**	**Metal**	**Average**
pH	4.7	Phosphorous	180
Oil and Grease	4000	Potasium	2270
BOD5	25000	Magnesium	615
COD	50000	Calcium	439
Total Solids	40500	Boron	7.6
Suspended Solids	18000	Iron	46.5
Total Volatile Solids	34000	Manganese	2.0
Ammonical Nitrogen	35	Copper	0.89
Total Nitrogen	750	Zinc	2.3

*All in mg/l except pH

2.3 Pollution Load and Effect of Discharge

The production of CPO in 2003 increased markedly by 12.1% or 1.4 million tons to 13.35 million tons from 11.91 million tons in 2002 (Malaysian Palm Oil Board, 2004) which is about 46,000 cubic meters per day. Based on this quantity of daily CPO production, the total quantity of effluent generated per day can be averaged up to 161,000 m^3 and the total BOD load of raw effluent generated per day is about 4,025 tons. Finally the population-equivalent of raw effluent BOD3 load (0.05 kg BOD/Capita/Day) is equal to 64,000,000 persons.

The above pollution statistics indicate that if the entire palm oil industry discharges raw effluent, then the total pollution load of the industry would be equivalent to that of a POME when discharged untreated or partially treated into the river stream undergoes natural decomposition during which the dissolved oxygen of the river or stream is rapidly depleted (Oil Palm & The Environment A Malaysian Perspective, 1999). The palm oil present in the effluent may float to the surface of the waterbody and form a wide-spread film which can efficiently cut-off and avert atmospheric oxygen from dissolving into its waters. Furthermore, when the organic load far exceeds its waste assimilation capacity, the available oxygen in the waterbody is rapidly consumed as a result of the natural biochemical processes that take place. The waterbody may become completely devoid of dissolved oxygen. This will lead to anaerobic conditions in which hydrogen sulphide and other malodorous gases are generated and released to the environment resulting in objectionable odors. Additional damaging effects include the decline and eventual destruction of aquatic life and deterioration in the riverine eco-system. Hence serious measures have to be taken in order to prevent the growing pollution caused by palm oil mill effluents.

2.4 Regulatory Control of Effluent Discharge

Oil palm cultivation and processing are regulated by a number of environmental legislations aimed at conserving and protecting the natural environment. These rules and regulations, together with the growing awareness for a clean and pollution-free environment play a significant role in minimizing the degradation of the soil, water and atmospheric environment. The DOE being the government agency acted responsibility in enacting the Environmental Quality Act in 1974 (EQA) and specific regulations for palm oil mill effluent in 1977.

EQA is an enabling act aimed to prevent, abate and control pollution for the protection of public health and the environment. The highlighting agenda of EQA was to set acceptable standards for the emission and discharge or deposits of pollutants into the environment rather than prevention, with an exception given to the necessities on environmental impact measurements. Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977 were promulgated under the Section 51 Environment Quality Act 1974 for environmental control of palm oil mills discharge. The regulatory standards for watercourse discharge were made effective from 15th July 1978 (Ma et aI, 1982) as shown in Table 2.4.

Table 2.4: Regulatory standards for palm oil mill effluent (Source: Ma et al, 1982)

Parameter	**Standard A 1.7.1978**	**Standard B 1.7.1979**	**Standard C 1.7.1980**	**Standard D 1.7.1981**
Biological oxygen Demand (BOD)	5000	2000	1000	500
Chemical oxygen Demand (COD)	10000	4000	2000	1000
Total solids (TS)	4000	2500	2000	1500
Suspended solid (SS)	1200	800	600	400
Oil & Grease (O&G)	150	100	75	50
Ammoniacal nitrogen (NH_3-N)	25	15	15	10
Organic nitrogen	200	100	75	50
pH	5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0
Temperature ^{0}C	45	45	45	45

All except pH in mg/L

2.5 Anaerobic Digestion

Biological treatment processes are cost effective processes that utilize microbial communities of varying degrees of diversity that interact in a multitude of ways to mediate a myriad of biological reactions (Wise, 1987, Jans and Man, 1988). Anaerobic digestion has been widely accepted as an effective alternative for wastewater treatment and simultaneous fuel gas production. Its successful application arises from the development of new and innovative reactor designs (Surampalli and Tyagi, 2004).

Compared to conventional aerobic methods of wastewater treatment, the anaerobic wastewater treatment concept indeed offers fundamental benefits such as low costs, energy production, relatively small space requirement of modern anaerobic wastewater treatment systems, very low sludge production (10-20% of COD removed) with very high dewaterability, stabilized sludge and high tolerance to unfed conditions (Lettinga, 1995; Droste 1997; Metcalf and Eddy, 2003).

Previously, perceived drawbacks of anaerobic treatment systems such as high susceptibility of microbes (in particular methanogens) to a variety of aenobiotic compounds, low stability of the process and long start-up period, could be attributed to lack of knowledge of the basic principles of the process. As a matter of fact, the anaerobic digestion process is highly stable, provided the system is operated in the proper conditions. It may be needed that optimum operational conditions to be determined for each particular type of wastewater and more importantly, the process must be sufficiently understood by engineers and operators (Lettinga, 1995).

APPENDIX B

Data of Concentration CH_4 on 9 Sept 2011 using GC

Report day 9/9/2011

Time	LD500 CH4 Conc.CH4 Path 1 %	LD500 Light, Path 1 dB	LD500 CH4 Psure P1 kPa	LD500 CH4 Temp P1 °C	LD500 MainFlow CH4 Kg/Hr Kg	LD500 Norm- alised P1`
00:00	65.46	39.14	101.83	31.65	2.06	0.57
01:00	66.48	38.90	102.02	31.41	0.27	78.60
02:00	68.83	38.93	101.83	31.34	38.78	22.71
03:00	70.43	38.69	101.62	30.95	11.47	3.00
04:00	71.72	38.21	101.59	30.28	1.54	0.41
05:00	72.66	38.09	101.59	30.11	0.21	0.40
06:00	73.42	37.92	101.61	29.85	0.21	0.40
07:00	69.77	37.42	101.64	29.52	0.20	0.39
08:00	69.60	37.80	115.50	31.79	0.20	-5.35
09:00	71.82	41.42	101.67	31.82	-2.75	0.37
10:00	65.38	50.07	101.58	37.25	0.17	0.29
11:00	60.47	50.20	101.52	42.65	0.13	0.24
12:00	59.00	49.13	101.48	45.86	0.10	0.23
13:00	59.53	47.94	101.31	46.87	0.10	0.23
14:00	58.08	47.69	101.25	44.61	0.10	0.26
15:00	57.60	47.43	101.08	43.21	0.11	0.26
16:00	58.95	48.49	114.52	45.32	0.11	-5.25
17:00	64.12	50.40	101.53	39.01	-2.41	69.33
18:00	60.27	43.39	101.61	35.26	29.95	24.55
19:00	58.71	36.13	101.69	31.44	10.33	40.10
20:00	58.97	36.03	101.75	31.17	16.95	13.04
21:00	60.71	35.63	101.90	30.31	5.67	3.03
22:00	62.79	35.55	101.94	29.94	1.37	0.95
23:00	64.90	35.57	101.89	29.53	0.44	0.50
Mean	64.57	41.67	102.75	35.05	4.80	10.39
Max	73.42	50.40	115.50	46.87	38.78	78.60
Sum					115.30	249.28
Meas.	24	24	24	24	24	24
Cover.	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Values with a star (*) in front are estimated.

Report created 9/17/2011 12:19:45. Signature: